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Die angehefteten Stücke sind eine richtige und genaue Wiedergabe der ursprünglichen Unterlagen dieser Patentanmeldung.

München, den 23. Mai 2003
Deutsches Patent- und Markenamt
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A METHOD AND A SYSTEM FOR IMPROVING THE EFFICIENCY OF A MECHANICAL ALIGNMENT TOOL

A METHOD AND SYSTEM FOR IMPROVING THE EFFICIENCY OF A MECHANICAL ALIGNMENT TOOL

FIELD OF THE PRESENT INVENTION

The present invention relates to the field of fabrication of integrated circuits, and, more particularly, to a technique for mechanically aligning a substrate with respect to a process tool, such as a photolithography tool.

DESCRIPTION OF THE PRIOR ART

Fabrication of integrated circuits requires the precise formation of very small features with a very small tolerance for error. Such features may be formed in a material layer formed above appropriate substrate, such as a silicon substrate. These features of precisely controlled size are generated by patterning the material layer by performing known photolithography and etching processes, wherein a masking layer is formed over the material layer to be treated to define these features. Generally, a masking layer may consist of or is formed by means of a layer of photoresist that is patterned by a lithographic process. During the lithographic process, the resist may be spin-coated onto the wafer surface and is then selectively exposed to ultraviolet radiation. After developing the photoresist, depending on the type of resist, positive resist or negative resist, the exposed portions or the non-exposed portions are removed to form the required pattern in the layer of photoresist. Since the dimensions of the patterns in sophisticated integrated circuits are steadily decreasing, the equipment used for patterning device features have to meet very stringent requirements with regard to resolution and overlay accuracy of the involved fabrication processes. In this respect, resolution is considered as a measure specifying the consistent ability to print images of a minimum size under conditions of predefined manufacturing variations. One important factor in improving the resolution is represented by the lithographic process, in which patterns contained in a photo mask or reticle are optically transferred to the layer of photoresist via an optical imaging system. Therefore, great efforts are made to steadily improve optical properties of the lithographic system, such as numerical aperture, depth of focus and wavelength of the light

source used. The quality of the lithographic imagery is extremely important in creating very small feature sizes.

Of at least comparable importance, however, is the accuracy with which an image can be positioned on the surface of the substrate. Integrated circuits are typically fabricated by sequentially patterning material layers, wherein features on successive material layers bear a spatial relationship to one another. Each pattern formed in a subsequent material layer has to be aligned to a corresponding pattern formed in the previously patterned material layer within specified registration tolerances.

These registration tolerances are caused by, for example, a variation of a photoresist image on the substrate due to non-uniformities in such parameters as resist thickness, baking temperature, exposure and development. Furthermore, non-uniformities of the etching processes can also lead to variations of the etched features. In addition, there exists an uncertainty in overlaying the image of the pattern for the current material layer to the pattern of the previously formed material layer while photolithographically transferring the image onto the substrate. Several factors determine the ability of the imagery system to overlay two layers, i.e., the existing layer and the layer to be transferred from the reticle to the substrate, such as imperfections within a set of masks, temperature differences at the different times of exposure, and a limited alignment capability of the alignment tool, which is commonly a part of the photolithography tool.

In commonly available photolithography tools, such as steppers that accomplish exposure of substrates in a step - and - repeat process, the substrates are typically aligned in a two-step procedure, wherein first in a so-called prealignment a coarse orientation of the substrate is achieved in that prominent positions of the substrate, located for example, at the substrate edge, are adjusted such that alignment marks within the substrate are positioned within a specified capture range of a fine alignment system. Then, in a subsequent fine alignment the actual registration of the substrate, or portions thereof when a die-by-die alignment is required, is accomplished. During the two-step alignment the substrate is placed on a substrate stage and is then aligned by, for example a two-dimensional translation

and a rotation in the plane defined by the two-dimensional translations, with respect to tool specific alignment marks. The accuracy of the alignment depends on, among other things, how the incoming substrate is placed on the substrate stage. This process may provide appropriate precision when the prealignment process is able to position the substrate with a sufficient degree of precision that allows the subsequent fine alignment routines to obtain the finally required accuracy. Thus, when the prealignment leads to an alignment result not falling within a specified process "window" a process abort may result, since the fine alignment procedure may not be able to locate alignment marks on the substrate, thereby significantly reducing the throughput of the lithography tool. In other cases, an inappropriate prealignment may entail a significant alignment error owing to a certain "periodicity" of the fine alignment procedure, yet resulting in a precise orientation, however, with a considerable translatory offset corresponding to the periodicity. Consequently, reworking of the substrate is required when the alignment error is detected by inspection, or a failure in subsequent processes may occur when the misalignment remains undetected. In either case, the throughput of the lithography is considerably reduced.

The prealignment process may be based on tool specific constants, such as offset values for the tool focus, basic settings for sensor and actuator elements, and the like. These constants may be determined during a qualification process, thereby possibly taking into account a specified type of substrates having experienced a specified one or more process sequences. However, a parameter drift in the tool and/or variations on the substrate side may lead to significant variations of the alignment procedure and thus entail the above-discussed disadvantages.

In view of this situation it is desirable to provide a technique for aligning substrates on the basis of alignment tool specific and substrate specific parameters, wherein a parameter drift may be compensated for or at least considerably be reduced.

SUMMARY OF THE INVENTION

Generally, the present invention is directed at a technique in which at least one tool constant that is relevant for the alignment procedure is updated, during the processing of a

batch of substrates, on the basis of at least one previously used value of the tool constant to thereby compensate tool related parameter drifts. Moreover, at least one substrate specific characteristic may be taken into account to thereby also reduce substrate specific parameter drifts.

According to one illustrative embodiment of the present invention, a method of aligning a substrate comprises obtaining first position data indicating a position of a first substrate having a predefined characteristic after an alignment act of the first substrate. Then a setpoint is determined for aligning a second substrate on the basis of the first position data and said predefined characteristic. Finally, the second substrate is aligned on the basis of the determined setpoint.

According to another illustrative embodiment of the present invention, a method of aligning a substrate comprises determining an input value of a first variable indicating a motion of a first substrate having a predefined characteristic during an alignment act of the first substrate. A setpoint for a second variable is determined on the basis of the first variable and the predefined characteristic, wherein the second variable indicates a motion of the second substrate during an initial phase of aligning the second substrate. Finally, the second substrate is aligned on the basis of the determined setpoint.

According to still another illustrative embodiment of the present invention an automatic alignment system comprises a substrate stage configured to receive and hold in place a substrate and a drive assembly that is mechanically coupled to the substrate stage and configured to initiate a motion of the substrate stage in response to a control signal. The alignment system further comprises a control unit configured to provide the control signal to the drive assembly. The control unit is further configured to establish the control signal on the basis of a predefined characteristic of a substrate to be aligned and position data obtained from one or more substrates previously aligned by the alignment tool.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages, objects and embodiments of the present invention are defined in the appended claims and the following description and will become more apparent by studying the following detailed description with reference to the accompanying drawings in which:

Fig. 1 schematically shows a metrology system adapted to perform an overlay accuracy measurement in accordance with one illustrative embodiment of the present invention;

DETAILED DESCRIPTION OF THE INVENTION

While the present invention is described with reference to the embodiments as illustrated in the following detailed description as well as in the drawings, it should be understood that the following detailed description as well as the drawings are not intended to limit the present invention to the particular illustrative embodiments disclosed, but rather the described illustrative embodiments merely exemplify the various aspects of the present invention, the scope of which is defined by the appended claims.

In the following illustrative embodiments, the present invention is disclosed in the specific context of its use with a photolithography tool, such as a stepper, since the present invention is particularly advantageous applicable in lithography processes to significantly increase tool efficiency due to an improved alignment technique. However, the present invention may as well be applied to other tools used during the production and/or inspection of substrates. For instance, in some metrology tools, such as scanning electron microscopes, scatterometers, and the like, valuable and sensitive measurement data may be obtained, wherein the demand for a high tool utilization calls for highly automated processes for substrate loading and aligning. Thus the speed and efficiency of the alignment process may significantly

improve throughput of the tools and thus allow more powerful process control due to an increased number of measurements per time.

With reference to Fig. 1 further illustrative embodiments will now be described.

Fig. 1 provides a schematic perspective view of a photolithography tool 100. The photolithography tool 100 is comprised of an optical system 101 that is configured to provide a light beam 102 of specified characteristics required for imaging a pattern onto a substrate. The optical system 101 may include an appropriate light source (not shown) a large number of complex optical components, such as lenses and mirrors to define an optical path for the light beam 102. Typically, a wavelength of the light used may be in the deep ultraviolet range, for example at 248 nm. In future tool generations, however, even shorter wavelengths may be used, wherein the optical components may correspondingly be adapted to these shorter wavelengths, by for example replacing refractive components by reflecting components. A substrate stage 103 is mechanically connected to a drive assembly 104, which in the present example is configured to be able to translate in two orthogonal directions, as indicated by reference sign 105, and to rotate, as indicated by 106, in a plane defined by the two translatory motions 105. In other embodiments, however, any number of degrees of freedom may be provided by the drive assembly 104. For example, a three-dimensional translatory movement may be provided and/or rotational or tilt motions in two or more different planes may be required for a precise alignment of a substrate 107 located on the substrate stage 103.

A reticle 108 is located in the optical path of the light beam 102 and includes an alignment mark 109 that represents a tool-internal coordinate system to which the substrate 107 or portions thereof is to be aligned. For convenience, any means necessary for handling and holding the reticle 108 are not shown. In tools other than the photolithography tool 100, for example, in a metrology instrument, the tool-internal coordinate system may be represented by any other alignment mark that allows the positioning of the substrate 107 with respect to the tool.

As shown, the substrate 107 may include at least one portion 110 having formed therein an alignment mark 111 that substantially corresponds to the alignment mark 109. In the example shown, the alignment marks 109 and 111 are of simple configuration, wherein in other embodiments the alignment marks 109 and 111 may have any more or less complex structure that enables an alignment within a predefined tolerance. Usually, the alignment mark 111 has dimensions and an internal structure as well as optical characteristics that are related to the circuit patterns to be transferred from the reticle 108 to the substrate portion 110 and process sequences performed during the manufacturing of the layer(s) including the portion 110. Thus, the ability of an automatic alignment procedure may depend on these characteristics. Furthermore, the structure, dimensions and characteristics of the alignment mark 111 may also affect a so-called capture range of a fine alignment system, which may be comprised of parts of the optical system 101, the drive assembly 104 and a control unit 112 that is operatively connected to the drive assembly 104 and possibly to other components of the tool 100. In other embodiments, the fine-alignment system may include separate and/or additional components (not shown). The control unit 112 may further be configured to operate the tool 100 and in particular the drive assembly 104 on the basis of positioning data used during aligning of one or more previously processed substrates and on the basis of one or more substrate characteristics, as will be described in more detail later on.

During operation, the substrate 107 is loaded on the substrate stage 103 by a corresponding substrate handler (not shown), wherein the location and orientation of the substrate 107 with respect to the substrate stage 103 may depend on various parameters, such as position of the substrate 107 relative to a cassette, the slot, in which the substrate 107 is placed within the cassette, tolerances caused during the substrate loading, and the like. Due to the limited ability of finely aligning the substrate 107, i.e. aligning the alignment mark 111 relative to the alignment mark 109, the substrate 107 has to be positioned on the substrate stage 103 within specified margins, also referred to as a prealignment window. Consequently, a prealignment procedure is carried out to coarsely align the substrate 107 by using prealignment characteristics of the substrate 107, such as a notch formed on the substrate perimeter or other marks, e.g., wafer flats, preferably formed at peripheral

regions of the substrate 107, which may easily be identified by the optical system 101 or other optical or mechanical sensor elements (not shown) that communicate with the control unit 112.

In a conventional device, the control unit 112 typically determines the translation 105 of the substrate stage 103 and/or the rotation 106 during the coarse alignment on the basis of fixed setpoints. The control unit 112 is configured to update one or more setpoints for the motions during the prealignment on a regular basis. As previously noted, the setpoints are conventionally determined by qualification procedures, thereby adjusting tool specific constants, such as electrical and/or mechanical variations of actuators, sensor elements, optical elements, and the like. In sophisticated integrated circuits, minimal overlay errors of some nanometers are required. Even minor tool variations may lead to an increased prealignment inaccuracy that may not allow a satisfactory fine alignment as is necessary for meeting the process specifications. Therefore, the setpoint(s) for the motions during prealignment are updated by taking advantage of the fact that positioning data gathered after a successful alignment of one or more previously finely aligned substrate may be used to redefine the setpoint(s) for the prealignment process.

In one embodiment, for each setpoint used for the prealignment, a corresponding target value is established, wherein the target value also includes one or more substrate specific characteristics, such as type of substrate, type of process sequence carried out during the formation of the alignment mark 111, type of reticle used, and the like. For example, a certain type of alignments mark 111 formed in or on a specified material layer may require a more restricted range of motions during the prealignment to ensure a successful fine-alignment compared to other substrate levels, which provide for alignment marks exhibiting improved contrast and thus enhanced likelihood of correctly identifying the alignment marks. Thus, the target values may represent the desired values for an appropriate prealignment window with respect to a given substrate characteristic.

Without intending to limit the present invention to a particular type and number of degrees of freedom unless otherwise explicitly set forth in the appended claims the motions performed during the alignment of the substrate 107 may be referred to as

x and y movements for the two orthogonal translatory motions 105 and as r for the rotation 106. The setpoints for the prealignment motions in these directions may be indicated by X, Y, R, respectively, wherein an index "first" may be used for a prealignment setpoint of a previously substrate, and an index "second" for the setpoint of the prealignment motions for the substrate 107 that is to be aligned. The target values for the setpoints may be denoted by $X_{t,k}$, $Y_{t,k}$ and $R_{t,k}$, wherein the index k relates to the substrate specific characteristic, and may represent the layer including the alignment mark 111 and the layer to be formed on and/or by means of the alignment mark 109 in the reticle 108. Thus:

X_{first}, Y_{first}, R_{first} represent the setpoints for prealignment of a previous, first substrate,
X_{second}, Y_{second}, R_{second} represent updated setpoints for the prealignment of the substrate 107, that is the second substrate, and
$X_{t,k}$, $Y_{t,k}$, $R_{t,k}$ represent the target values ensuring a prealignment within the capture range of the fine-alignment, thereby taking into account the substrate characteristics.

In one embodiment, the updated setpoints are determined by using the position data of the first (previous) substrate(s) as "measurement" data or input data, wherein the first substrate is assumed to have been properly aligned by the fine-alignment algorithm implemented in the control unit 112. In some embodiments, the input data may be obtained from a plurality of first substrates, for example from a previously processed lot by appropriately averaging the data or by selecting a corresponding input values in accordance with certain selection criteria specifying a suitable candidate. For instance, values having a significant deviation from the plurality of data may be ignored, thereby minimizing the risk to include data of incorrectly aligned substrates. However, any other suitable selection criteria may be applied when a plurality of first substrates is used. The position data for the one or more first substrates may be denoted by x_{first}, y_{first}, r_{first}, wherein it is to be borne in mind that these position data are related to the substrate characteristic k and is for convenience not indexed in the position data.

For determining the updated setpoints X_{second}, Y_{second}, R_{second} for properly prealigning the (second) substrate 107 a relationship may be established relating the input data x_{first}, y_{first}, r_{first} to updated setpoints X_{second}, Y_{second}, R_{second} and the previously used setpoints X_{first}, Y_{first}, R_{first} such that a drift of the input data x_{first}, y_{first}, r_{first}, indicating a tool and/or substrate specific variation may be compensated for by correspondingly redefining the setpoints X_{first}, Y_{first}, R_{first} to obtain the updated setpoints X_{second}, Y_{second}, R_{second} accounting for the parameter variation. A corresponding relationship may be established by experiment, for instance by monitoring the alignment accuracy for a large number of substrates and analyzing the corresponding data to obtain a correlation between the input data and the setpoints for the prealignment.

In one particular embodiment, a model is used to find a relation between the input data x_{first}, y_{first}, r_{first} and the updated setpoints X_{second}, Y_{second}, R_{second} to be used for prealigning the substrate 107. In one illustrative embodiment, a linear model may be used, wherein the individual motions corresponding to the individual degrees of freedom are not mixed. A corresponding relationship in a linear model may take on the following form:

$$x_{second} = x_{first} + a(X_{second} - X_{first})$$
$$y_{second} = y_{first} + b(Y_{second} - Y_{first})$$
$$r_{second} = r_{first} + c(R_{second} - R_{first}),$$

wherein x_{second}, y_{second} and r_{second}, respectively represent the position data for aligning the (second) substrate 107. The parameters a, b and c may represent sensitivity parameters for quantitatively describing the “effect” of a change in the setpoint to the alignment operation. For instance, the parameters a, b and c may be selected as 1. In other embodiments, one or more of the sensitivity parameters may be less than 1 to “dampen” the effect of the prealignment on the entire alignment process, whereas in other variants, one or more sensitivity parameters may be higher than 1 to enhance the influence of the prealignment process.

In order to determine the updated setpoints X_{second}, Y_{second}, R_{second} fictitious optimal setpoints for the first substrate, indicated as X^*, Y^* and R^*, respectively, may be

calculated by using the target values $X_{t,k}$, $Y_{t,k}$ and $R_{t,k}$ for the prealignment setpoints according to the above specified model. Thus, solving the following equation:

$$X_{t,k} = x_{first} + a(X^* - X_{first})$$
$$Y_{t,k} = y_{first} + b(Y^* - Y_{first})$$
$$R_{t,k} = r_{first} + c(R^* - R_{first}),$$

may yield the optimal settings for the prealignment operation of the first (previous) substrate. From the above fictitious optimal setpoints X^*, Y^* and R^* of the first substrate respective estimates for the setpoints for the prealignment of the substrate 107 may be predicted by assuming a relationship between the setpoints X_{first}, Y_{first}, R_{first} actually employed in aligning the first substrate and the calculated fictitious optimal setpoints X^*, Y^* and R^* on the one hand, and the behavior of the prealignment process for the substrate 107, i.e., the setpoints X_{second}, Y_{second}, R_{second}, on the other hand. According to one illustrative embodiment, an exponentially weighted moving average (EWMA) operation may be used to provide estimated setpoints for the substrate 107, indicated as $X^{\sim}_{second}$, $Y^{\sim}_{second}$, $R^{\sim}_{second}$, wherein the weighing factors may be determined in advance, for example by experiment or simply by selecting them based on experience. The estimated setpoints may be obtained from the following equation:

$$X^{\sim}_{second} = \lambda X^* + (1-\lambda) X_{first}$$
$$Y^{\sim}_{second} = \mu Y^* + (1-\mu) Y_{first}$$
$$R^{\sim}_{second} = \nu R^* + (1-\nu) R_{first},$$

wherein the coefficients λ, μ and ν represent the weighing factors taking on values in the range from 0...1, thereby determining the amount of influence of the previously actually used setpoints X_{first}, Y_{first}, R_{first} with respect to the calculated optimal setpoints $X^{\sim}_{second}$, $Y^{\sim}_{second}$, $R^{\sim}_{second}$. The coefficients λ, μ and ν therefore also affect the "speed" at which the prealignment process for the substrate 107 "responds" to a deviation of the actual setpoints form the setpoints that would have been optimal in prealigning the first substrate. For instance, a value λ=1 would cause an immediate response to a deviation of the actual setpoint and the optimal setpoint without taking into consideration the "history" of preceding alignment

processes, which is represented by the actually used setpoint X_{first}. Thus, in some embodiments, it may be advantageous to select the coefficients from the range of approximately 0.1 to 0.9, and in other embodiments from about 0.3 to 0.8. In still other embodiments, the same value may be selected for all coefficients λ, μ and ν. This may be considered appropriate when the motions for aligning the substrates and represented in the above embodiments by x, y and r are quite similar, that is, are physically similar and/or are effected by similar mechanical and electronic components. For instance, the x motion and the y motion are substantially identical so that a common coefficient λ may be appropriate, whereas the rotation r may involve differently configured actuators, sensors and the like, thereby possibly providing enhanced control results when the coefficient ν is selected independently from one or more of the other coefficients. It should be noted in this context that the representations of the different motions, such as x, y and r have to be provided in an appropriately normalized fashion such that identical values for the coefficients may be used for the various representatives. If it is for example considered appropriate to use the same coefficient for x, y and r, the r variable may be converted in a suitable representation, i.e., the actually used numerical value, that conforms to the representations for the x and y variables. That is, the x and y variables may actually be represented by dimensional quantities with respect to absolute dimensional magnitudes, such as nanometers, Angstrom, and the like, or may be represented by tool internal units, or by other tool parameters, such as current and/or voltage values of respective actuator elements, and the like. In order to provide for correspondingly "normalized" rotational data r, the r representation, i.e., the actual value of the rotation, may be selected so as to obtain a similar effect of the rotation r at the position of the alignment mark 111 compared to a translation (x,y) when a similar value for the x,y and the r representations is used.

In one particular embodiment the estimated setpoints $\tilde{X}_{second}$, $\tilde{Y}_{second}$, $\tilde{R}_{second}$ for the prealignment of the substrate 107 may not be directly employed, but instead may be used to calculate the setpoints X_{second}, Y_{second}, R_{second} that are then actually supplied by the control unit 112 to carry out the alignment operation. In this way, a smooth behavior of the control operation may be accomplished in that the development of previous alignment procedures is taken account of. For instance,

the setpoints X_{second}, Y_{second}, R_{second} may be calculated in such a way that each of these setpoints is "centered" around the respective estimated setpoint $\tilde{X}_{second}$, $\tilde{Y}_{second}$, $\tilde{R}_{second}$, wherein the deviation from the previously used setpoints X_{first}, Y_{first}, R_{first} is taken into consideration by, for example, minimizing this deviation. In one embodiment, a corresponding determination of the finally used setpoints X_{second}, Y_{second}, R_{second} may be achieved by solving a squared minimization approach, which may be written in the form:

$$\min \{u (\tilde{X}_{second} - X_{second})^2 + v (\tilde{X}_{second})^2 + w (\tilde{X}_{second} - X_{first})^2\}$$
$$\min \{u (\tilde{Y}_{second} - Y_{second})^2 + v (\tilde{Y}_{second})^2 + w (\tilde{Y}_{second} - Y_{first})^2\}$$
$$\min \{u (\tilde{R}_{second} - R_{second})^2 + v (\tilde{R}_{second})^2 + w (\tilde{R}_{second} - R_{first})^2\},$$

wherein the problems are to be solved for X_{second}, Y_{second}, R_{second}, respectively by varying the $\tilde{X}_{second}$, $\tilde{Y}_{second}$, $\tilde{R}_{second}$ to minimize the above expressions. To this end, the X_{second}, Y_{second}, R_{second} may be replaced by the target values for the setpoints or by any other desired values. Varying of the estimated setpoints $\tilde{X}_{second}$, $\tilde{Y}_{second}$, $\tilde{R}_{second}$ may be achieved by, for example, varying the coefficients λ, μ and ν in the above explained EWMA approach. The coefficients u, v, w used in minimizing the square sums may be selected so as to appropriately weigh the control behavior with respect to the previously employed setpoints X_{first}, Y_{first}, R_{first} and the estimated setpoints. For example, the estimated setpoints $\tilde{X}_{second}$, $\tilde{Y}_{second}$, $\tilde{R}_{second}$ may be determined such that the difference to the previously setpoints and to the target setpoints is minimized, wherein the influence of these differences on the setpoints to be used in prealigning the substrate 107 is controlled by the coefficients u and w. It is to be noted that the coefficients u, v and w in the above square sums may be selected differently for the respective motions.

It should be noted that the position data x, y, r, the setpoints, and the like are referred to as variables. It is herein intended, unless otherwise set forth in the claims, that a single variable is also to denote a plurality of magnitudes, such as different types of motion, and the like, which may be provided as a vector representation.

Again referring to Fig. 1, a control process in conformity with one of the above embodiments is performed by the control unit to generate a control signal that is

supplied to the drive assembly 104 to move the substrate 107 in accordance with the above-established prealignment setpoints X_{second}, Y_{second}, R_{second}. Any parameter drift in the tool and/or the substrate 107 compared to the parameter values in one or more of preceding alignment operations may thus be significantly be reduced. Consequently, the substrate 107 is positioned more precisely with the prealignment window and alignment failures in the subsequent fine-alignment are also reduced. In one embodiment, the control unit 112 is configured to process a plurality of substrates 107, for example on a lot basis, with the established prealignment setting before establishing a new set of prealignment setpoints. The positioning data x_{first}, y_{first}, r_{first} obtained after aligning the substrate 107 are stored in an appropriate storage medium (not shown), for example provided within the control unit, and may be used as "measurement" or input data for one or more substrates to be next processed by the tool 100. Although these input data may not exactly represent the physical position of the substrate 107 after alignment, there is a correlation of the position data and the actual exposure position and therefore an accuracy of the input data substantially corresponds to the accuracy of the fine-alignment process. As a consequence, the accuracy of the input data is sufficient to detect relevant tool and/or substrate drifts regarding the prealignment procedure, which may then effectively be compensated for by the above-described processes. The embodiments described above may be implemented in the control unit 112 by means of a set of instructions that may be executed by an appropriate logic circuit, or the updated setpoint data that has been calculated in advance for a specified range of input data are stored in data base or library and may be retrieved by the control unit 112 on the basis of the input data obtained by previously processed substrate.

In other embodiments, threshold values may be set for one or more degrees of freedom to monitor the development of the updated setpoints and cause a suitable action upon crossing a corresponding threshold. In this way, for instance a systematic drift of the tool 100 or the substrates 107 may be recognized and a warning or an invalid machine status may be reported to an operator or a commanding facility management system.

The configuration of the control unit 112 may be realized in may different ways, including, but not limited thereto, a software program and/or a data base installed in a control unit of a conventional alignment tool, a separate computer device connected to the tool 100 by means of a wired and/or wireless communications line, a program in the facility management system, and the like.

As a result, the present invention provides a technique in which the position data of one or more previously aligned substrates are used as “measurement data” for the alignment process of one or more following substrates. In particular embodiments, additional characteristics concerning the substrate, such as the type of substrate, the layers involved in the alignment process, and the like, is taken advantage of, for example by determining respective target setpoints including one or more of these characteristics, to determine a corresponding control value for e.g. a prealignment process. By centering the position after prealignment closer and more reliable around the capture range of the fine alignment process, the overall alignment efficiency may effectively be improved.

Further modifications and variations of the present invention will be apparent to those skilled in the art in view of this description. Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the present invention. It is to be understood that the forms of the invention shown and described herein are to be taken as the presently preferred embodiments.

CLAIMS

1. A method of aligning a substrate, the method comprising:

obtaining first position data indicating a position of a first substrate having a predefined characteristic after an alignment act of the first substrate;

determining a setpoint for aligning a second substrate on the basis of said first position data and said predefined characteristic; and

aligning said second substrate on the basis of said determined setpoint.

2. The method of claim 1, wherein obtaining first position data includes:

obtaining an input value of a first variable indicating a motion of the first substrate during the alignment act of the first substrate.

3. The method of claim 1, wherein determining said setpoint of the second substrate includes determining a second variable indicating a motion of said second substrate during an initial phase of aligning said second substrate.

4. The method of claim 1, further comprising obtaining second position data indicating a motion during said aligning of the second substrate.

5. The method of claim 2, wherein said first variable indicates at least a two-dimensional translatory motion.

6. The method of claim 2, wherein said first variable indicates at least one rotary motion.

7. The method of claim 1, further comprising providing a target value for said setpoint, wherein said target value is selected on the basis of said predefined characteristic.

8. The method of claim 7, wherein said setpoint is determined on the basis of said target value.

9. The method of claim 1, further comprising using a linear model relating said first position data and said setpoint to second position data of the second substrate and a previous setpoint used for aligning said first substrate.

10. The method of claim 9, wherein each of said first and second position data comprises at least two degrees of freedom and said relation provided by said linear model is devoid of a mixture of said at least two degrees of freedom.

11. The method of claim 1, further comprising defining said characteristic at least on the basis of a first layer, formed on the first and second substrates and including an alignment mark, and a second layer to be formed on the second substrate.

12. The method of claim 1, wherein said position data is determined from a plurality of first substrates.

13. The method of claim 1, wherein a plurality of second substrates are aligned on the basis of said setpoint.

14. A method comprising:

obtaining an input value of a first variable indicating a motion of a first substrate during an alignment act of the first substrate;

determining a setpoint for a second variable on the basis of said first variable, said setpoint of the second variable determining a motion of said second substrate during an initial phase of aligning said second substrate; and

aligning said second substrate on the basis of said determined setpoint.

15. The method of claim 14, further comprising:

obtaining a second input value of the first variable of the second substrate, the second input value indicating a motion during aligning the second substrate; and

and using said second input value for determining a setpoint for a third substrate to be aligned.

16. The method of claim 14, wherein said first variable indicates at least a two-dimensional translatory motion.

17. The method of claim 14, wherein said first variable indicates at least one rotary motion.

18. The method of claim 14, wherein said setpoint is determined on the basis of a predefined characteristic of said first and second substrates.

19. The method of claim 18, further comprising providing a target value for said setpoint, wherein said target value is selected on the basis of said predefined characteristic.

20. The method of claim 19, wherein said setpoint is determined on the basis of said target value.

21. The method of claim 14, further comprising using a linear model relating said first input value and said setpoint to a second input value of the first variable indicating the motion of the second substrate and a previous setpoint used for aligning said first substrate.

22. The method of claim 21, wherein said first variable comprises at least two degrees of freedom and said relation provided by said linear model is devoid of a mixture of said at least two degrees of freedom.

23. The method of claim 18, further comprising defining said characteristic at least on the basis of a first layer, formed on the first and second substrates and

including an alignment mark, and a second layer to be formed on the second substrate.

24. The method of claim 14, wherein said input value is determined from a plurality of first substrates.

25. The method of claim 14, wherein a plurality of second substrates are aligned on the basis of said setpoint.

26. An automatic alignment system comprising:

a substrate stage configured to receive and hold in place a substrate;

a drive assembly mechanically coupled to said substrate stage and configured to initiate a motion of said substrate stage in response to a control signal; and

a control unit configured to provide said control signal to the drive assembly, and further configured to establish said control signal on the basis of a predefined characteristic of a substrate to be aligned and position data obtained from one or more substrates previously aligned by said alignment tool.

27. A photolithography tool including an automatic alignment tool as defined in claim 26.

ABSTRACT

A technique is disclosed that allows to align substrates on a run-to-run basis by using the position data of one or more previously aligned substrates to determine a setpoint of a prealignment process for one or more subsequent substrates. The setpoint may also be determined on the basis of a predefined characteristics of the substrates to be aligned.

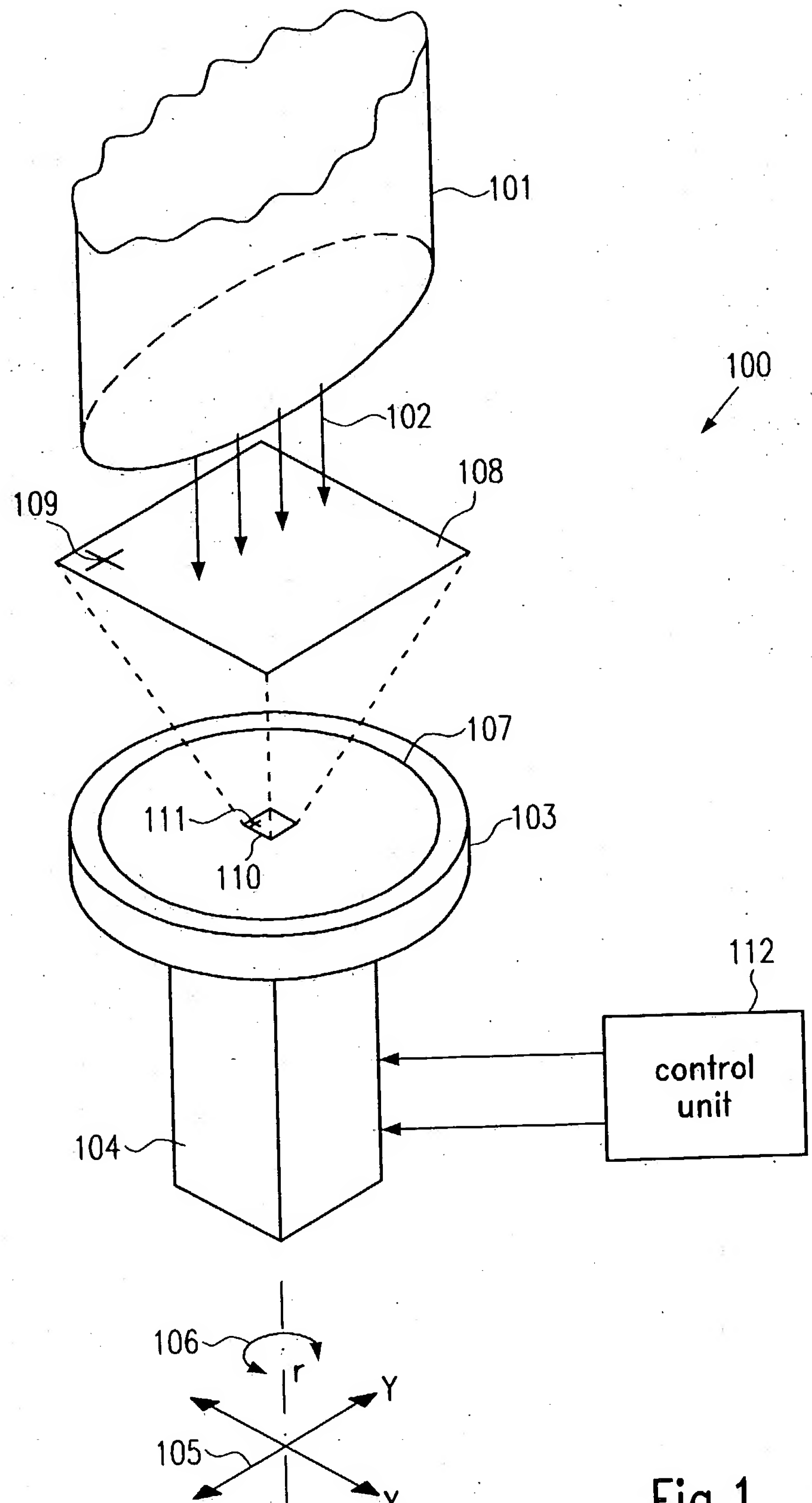
101
100
102
108
109
107
111
103
110
112
control unit
104
106
r
Y
105
X

Fig.1